Preliminary Notes on Mr. Hall's Recent Discovery.

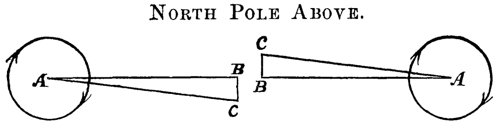
By H. A. Rowland.

The recent discovery by Mr. Hall of a new action of magnetism on electric currents opens a wide field for the mathematician, seeing that we must now regard most of the equations which we have hitherto used in electromagnetism as only approximate, and as applying only to some ideal substance which may or may not exist in nature, but which certainly does not include the ordinary metals. But as the effect is very small, probably it will always be treated as a correction to the ordinary equations.

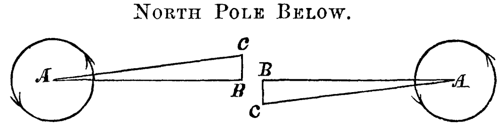
The facts of the case seem to be as follows, as nearly as they have yet been determined: Whenever a substance transmitting an electric current is placed in a magnetic field, besides the ordinary electromotive force in the medium, we now have another acting at right angles to the current and to the magnetic lines of force. Whether there may not be also an electromotive force in the direction of the current has not yet been determined with accuracy, but it has been proved within the limits of accuracy of the experiment that no electromotive force exists in the direction of the lines of magnetic force. This electromotive force in a given medium is proportional to the strength of the current and to the magnetic intensity, and is reversed when either the primary current or the magnetism is reversed. It has also been lately found that the direction is different in iron from what it is in gold or silver.

To analyze the phenomenon in gold, let us suppose that the line AB represents the original current at the point A and that BC is the new effect. The magnetic pole is supposed to be either above or below the paper as the case may be. The line AC will represent the final resultant electromotive force at the point A. The circle with arrow represents the direction in which the current is rotated by the magnetism.

North Pole Above.



North Pole Below.



It is seen that all these effects are such as would happen were the electric current to be rotated in a fixed direction with respect to the lines of magnetic force and to an amount depending only on the magnetic force and not on the current. This fact seems to point immediately to that other very important case of rotation, namely, the rotation of the plane of polarization of light. For, by Maxwell's theory, light is an electrical phenomenon and consists of waves of electrical displacement, the currents of displacement being at right angles to the direction of propagation of the light. If the action we are now considering takes place in dielectrics, which point Mr. Hall is now investigating, the rotation of the plane of polarization of light is explained.

I give the following very imperfect theory at this stage of the paper, hoping to finally give a more perfect one either in this paper or a later one.

Let $\mathfrak{H}$ be the intensity of the magnetic field, and let E be the original electromotive force at any point, and let $\mathfrak{c}$ be a constant for the given medium. Then the new electromotive force, E', will be

$$E' = \mathfrak{c}\,\mathfrak{H}\,E.$$

and the final electromotive force will be rotated through an angle which will be very nearly equal to $\mathfrak{c}\,\mathfrak{H}$. As the wave progresses through the medium, each time it, the electromotive force, is reversed it will be rotated through this angle, so that the total rotation will be this quantity multiplied by the number of waves. If λ is the wave length in air and i is the index of refraction and c is the length of medium, then the number of waves will be $\frac{ci}{\lambda}$ and the total rotation

$$\theta = c\,\mathfrak{c}\,\mathfrak{H}\frac{i}{\lambda}.$$

The direction of rotation is the same in diamagnetic and feromagnetic bodies as we find by experiment, being different in the two; for it is well known that the rotation of the plane of polarization is opposite in the two media, and Mr. Hall now finds *his* effect to be opposite in the two media. This result I anticipated from this theory of the magnetic rotation of light.

But the formula makes the rotation inversely proportional to the wave length, whereas we find it more nearly as the square or cube. This I consider to be a defect due to the imperfect theory, and it would possibly disappear from the complete dynamical theory. But the formula at least makes the rotation increase as the wave length decreases, which is according to experiment. Should an exact formula be finally obtained, it seems to me

that it would constitute a very important link in the proof of Maxwell's theory of light, and, together with a very exact measure of the ratio of the electromagnetic to the electrostatic units of electricity which we made here last year, will raise the theory almost to a demonstrated fact. The determination of the ratio will be published shortly, but I may say here that the final result will not vary much, when all the corrections have been applied, from 299,700,000 metres per second, and this is almost exactly the velocity of light. We cannot but lament that the great author of this modern theory of light is not now here to work up this new confirmation of his theory, and that it is left for so much weaker hands.

But before we can say definitely that this action explains the rotation of the plane of polarization of light, the action must be extended to dielectrics, and it must be proved that the lines of electrostatic action are rotated around the lines of force as well as the electric currents. Mr. Hall is about to try an experiment of this nature.

I am now writing the full mathematical theory of the new action, and hope to there consider the full consequences of the new discovery.